SYNOPSIS OF

GROWTH AND CHARACTERIZATION OF DIVALENT CATIONS DOPED TARTRATE SINGLE CRYSTALS

A THESIS

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SYNOPSIS

1 Introduction

Crystalline state is the most commonly encountered state of solid materials on earth. Under different temperature and pressure conditions, atoms naturally array into formation of crystalline shapes. Depending on conditions and the material, the process of natural crystallization can take place in a few days to a few thousand years. Several crystals in the earth's crust are formed over a time of the order of million years.

Crystals such as common salt are known to mankind over thousands of years as an integral part of food and culture. The salt crystals are grown by evaporating seawater in direct sun. Usefulness of various crystals in jewelry is an ancient practice. Precious stones, such as diamond, sapphire, ruby etc are generally considered as a valuable resource in addition to using them exclusively in the making of jewelry. India is the first country to mine diamonds.

1.1 Modern crystals

Crystals are the most important elements of modern technology including electronic, photonic, fiber optic communication and computer industries where crystals in the form of semiconductors, superconductors, polarizers, transducers, radiation detectors, amplifiers, lasers, etc are the most basic elements in the manufacturing of devices. The list of applications is almost endless. There has been a growing interest in crystal growth following increasing demand for materials for technological applications.

Quartz crystals are one of the common components in devices like cell phones, television receivers, clocks, etc. One most important aspect of quartz in this context is the piezoelectric property. Garnet crystals in sandpaper, corundum crystals in grinding wheels and durable sandpaper, diamonds in rock-cutting drill bits and saws, calcite crystals in making cement, gypsum crystals in making plaster, ruby crystals in lasers etc are some of the common industrial applications of crystals.

In the making of ornaments such as rings, necklaces, bracelets, and other cosmetic jewelry, crystals of diamond, sapphire, and ruby are in use for a long time. At present, thanks to advancement of technology, these crystals can be grown under controlled conditions in laboratories.

1.2 Crystal structure

A crystalline solid is formed by regular repetition of its building blocks, called *unit cells*, in a three dimensional periodic array. The unit cell of the crystal explains in detail the entire crystal structure and symmetry with the atomic positions along with its principal axes. The lengths of the edges of the unit cell (lattice constants, denoted by a, b, c) and the mutual angles between the three edges (denoted by α, β, γ) constitute lattice parameters that specify the crystal geometry. If the regularity/ periodicity of the arrangement of unit cells extends to a small piece of solid, then for certain scientific purposes the crystal is referred to as a single crystal [1].

A crystal system refers to one of the many classes of crystals, space groups, and lattices. Based on the point groups and space groups, crystals are categorized into seven crystal systems. Every

crystal system is identified by a unique set of lattice parameters. The atomic lattice is a series of atoms that are organized in a symmetrical pattern. From a lattice structure, it is possible to determine the appearance and physical properties of the crystal.

2 Motivation, Objectives and Scope

Strontium tartrate, one of many interesting crystal materials, has gained the attention of researchers in recent times. This has brought the gel method of growing crystals to forefront [2]. Strontium and calcium tartrate crystals exhibit interesting properties, such as dielectric, ferroelectric, optical nonlinearity, luminescence and magnetic properties that carry scientific and application values.

Tartrate salts exhibit various interesting properties. Members of tartrate family (including several divalent tartrates) are either ferroelectric or piezoelectric compounds exhibiting nonlinear optical and spectral characteristics. For example, Rubidium Hydrogen Tartrate (RHT) and Ammonium Hydrogen Tartrate (AHT) are both used extensively in controlling "Laser emission" [3]. Consequently, tartrates are used in transducers and several linear and nonlinear mechanical devices [3–6].

Crystal materials, namely, tartrates, phosphates, oxalates, citrates and tungstate have low solubility (or low dissociation temperature). These materials can be grown to large sizes with high optical quality only by using gel method [7]. Calcium tartrate crystal was first grown by Henisch [7] and its structure was first solved in the year 1982 by Hawthorne et al [8]. Gon confirmed that this crystal exhibits ferroelectric nature with a well-defined hysteresis loop [9]. Strontium tartrate single crystal is grown by gel method long ago, and the lattice parameters, space group and the crystal system relevant to this crystals are determined (from X-ray analysis) [10] to show that the tri- and tetrahydrates respectively belong to monoclinic (space group: $P2_1$) and orthorhombic (space group: $[P2_12_12_1]$) systems. Similar studies are made, and being made, by many authors. For the past several decades, the scientific community is focussed on discovering new crystalline materials to be used for the enhancement of present day technology.

Gel medium is observed to be an excellent medium for the growth of crystals under controllable conditions. Single crystals grown in gel are seen to be pure and are free from thermal strains [11]. For the first time, single crystals of calcium tartrate are grown by Henisch et al [7]; single crystals of calcite are grown by following a refined procedure of gel method [12]. Gel method is successfully tuned further to grow SrTr single crystals of relatively larger size and better purity as compared to earlier works [13]. Several advantages of gel method over other methods of growing single crystals are critically discussed by Arora [14] to show that, by using gel method, the rate of diffusion and probability of nucleation can be better controlled to obtain crystals of required size and morphology. In the study of growing lanthanum tartrate crystals, Kotru et al [15] found that the adsorption property of the gel plays a vital role in the process of crystallization. Rethinam et al [16] have discussed several aspects of growth of single crystals in gel, such as, dependence of size and transparency on concentration of dopant and introduction of new bonds due to doping. Interesting aspects related to growth of cadmium oxalate single crystals doped with monovalent and divalent cations are discussed by Jagannatha and Rao [17]. Studies of Rahimkutti [18] showed that, in the process of growth of single crystals, water molecules are likely to be locked up in the lattice with different strengths in the grown crystals. Shajan and Mahadevan [19] have discussed the role of formic acid in the growth of calcium tartrate crystals. Further it is observed that, by

using calcium formate mixed with formic acid as supernatant solution, the nucleation density is reduced while the size of the crystals are improved as compared to other conventional methods of growing calcium tartrate single crystals [19]. Large and practically perfect strontium tartrate trihydrate single crystals are grown in the studies of Arora et al [20] by the method of optimizing ionic diffusion by tuning the growth parameters. Large number of studies are available in the literature to date where practically pure single crystals of various chemical compositions are grown [21–40, for example]. Studies show that gel method yields crystals of better morphology and transparency as compared to crystals grown from earlier methods [41, for e.g.].

Thus, for the past several decades, gel method is adapted by researchers for growing single crystals of different compositions. It is also evident that discovering crystals of new materials is an important aspect of development of material science from the point of view of possibilities of using such materials in the modern scientific applications. In this context, simplicity and convenience of gel method in growing single crystals is noteworthy.

Once the crystals are grown, it is always desirable that the grown crystals are characterized in terms of several physical and chemical properties that are observable with the crystal under study. Before this, the morphology of the grown sample is ensured through FESEM analysis. The actual number of characterizing parameters for the crystal is large. However, depending on the technical resources available and accessible to the institution where research is carried out, the crystals are characterized in terms of as many characteristic parameters as possible. Such a characterization is essential from the point of view of using the crystal to various suitable scientific applications.

Hence, in the present work, several new crystalline materials are grown and their significant and characteristic properties are studied using several modern techniques with a purpose of assessing the usefulness of these materials for scientific/technological applications. Twelve different experimental techniques, used in the present work to characterize the grown single crystals, are listed in the following table:

3 Structure of contents

The present research work is organized into nine chapters. The contents of each of these chapters are briefly explained to have a comprehensive overview of the work. Further, these explanations are organized in a tabular manner so that it would become easier and simpler for appreciating the contents of the work. Important results of the present work has been shown in the next section.

Various instrumentations & techniques used in the present work		
Sl No	Name of Instrumentation/ Technique/Analysis used	Relevant characteristic information obtained about the experimental crystal
1	FESEM	• Crystal morphology
2	EDAX	• Elements present in the grown crystal • Atomic percentages of elements • Weight percentages of elements
3	SXRD	• Lattice parameters (Space group, Crystal system, cell volume) • Crystal habits (using `WinXMorph` software) • Angles between cell axes (α, β, γ) • Lengths of unit cell (a, b, c) • Crystal structure • Hirshfeld Surface Analysis: contribution of hydrogen bonds to crystal structure
4	PXRD	• Miller Indices (h, k, l) of crystal planes • Crystallinity of the material
5	FTIR spectroscopy	• Functional groups present in the crystal
6	Laser Raman	• Functional groups present in the crystal • Crystallinity of the material
7	TG-DTA	• Thermal stability • Activation energy • Presence of water of crystallization
8	UV-Visible spectral analysis	• Absorbance and Transmittance • Optical bandgap energy • Extinction coefficient
9	Kurtz-Perry technique	• SHG intensity • SHG efficiency
10	Impedance analyser	• Resistance & Resistivity • Quality factor & Dissipation factor • Capacitance, Dielectric constant, Dielectric loss • Refractive index & AC conductivity
11	Two-Probe method	• DC conductivity
12	Gouy balance technique	• Magnetic susceptibility & nature of magnetism

3.1 Chapter 1: Introduction to Crystal Growth

Printed structure	Pages: 12 | Sections: 7 | Figures: Nil | Tables: Nil | References: 24
Section headings	Introduction, Nucleation, Growth, Methods of crystal growth, Crystal growth in gel media, Methods of crystal growth in gels, Advantages of gel method over other methods
Highlights of work	• Extensive survey of literature related to the present work • Features and advantages of gel method of crystal growth

3.2 Chapter 2: Instrumentation and Methodology

Printed structure	Pages: 24 | Sections: 13 | Figures: 24 | Tables: Nil | References: 35
Section headings	Introduction Field Emission Scanning Electron Microscopic (FESEM) analysis Energy Dispersive X-ray Analysis (EDAX) Powder X-ray Diffraction analysis (PXRD) SXRD and Hirshfeld Surface Analysis (HSA) Fourier Transform Infrared spectral analysis (FTIR) LASER Raman spectroscopic analysis Thermo Gravimetric-Differential Thermal Analysis (TG-DTA) UV-Visible spectral analysis Kurtz and Perry technique: Determination of SHG efficiency Impedance analyser, Two-Probe method Magnetic susceptibility using Gouy balance
Highlights of work	• Brief description of modern instrumentation & techniques used in this study is made with all necessary illustrations. The methods of operating/using these instruments are also explained

3.3 Chapter 3: Growth and Morphology of the Grown Crystals

Printed structure	Pages: 23 | Sections: 9 | Figures: 17 | Tables: 8 | References: 12
Section headings	Introduction Experimental details Optimization condition of growth for the grown crystals Simulated Morphological studies Simulated Morphology of IST Simulated Morphology of doped strontium tartrate crystals Simulated Morphology of ICaT Simulated Morphology of doped calcium tartrate crystals
Highlights of work	• Gel method of growing single crystals is described in detail
	• Through a sufficiently large number of trials, the growth parameters are optimized for growing high quality single crystals of this study
	• Under optimized condition, two intrinsic and eleven doped varieties of single crystals are grown
	• The grown crystals are as follows: Intrinsic strontium tartrate pentahydrate (IST) Intrinsic calcium tartrate tetrahydrate (ICaT) Mg-doped strontium tartrate pentahydrate (ST), i.e., MDST Cu-doped ST, i.e., CuDST, Zn-doped ST, i.e., ZDST Mn-doped ST, i.e., MnDST, Cd-doped ST, i.e., CdDST Co-doped ST, i.e., CoDST Cu-doped calcium tartrate tetrahydrate (CaT), i.e., CuDCaT Zn-doped CaT, i.e., ZDCaT, Cd-doped CaT, i.e., CdDCaT Co-doped CaT, i.e., CoDCaT, Ni-doped CaT, i.e., NiDCaT
	• Crystal habits of all the crystals mentioned above are studied by simulating their morphology

3.4 Chapter 4: EDAX and FESEM Studies of the Grown Crystals

Printed structure	Pages: 13 | Sections: 5 | Figures: 13 | Tables: 13 | References: 1
Section headings	Introduction EDAX and FESEM studies of IST Crystal EDAX and FESEM studies of doped strontium tartrate crystals EDAX and FESEM studies of ICaT crystals EDAX and FESEM studies of doped calcium tartrate crystals
Highlights of work	• EDAX and FESEM studies of all grown crystals are made
	• EDAX spectra and SEM images of all the crystals are analyzed

3.5 Chapter 5: Thermal Studies of the Grown Crystals

Printed structure	Pages: 27 | Sections: 5 | Figures: 13 | Tables: 13 | References: 4
Section headings	Introduction TG-DTA studies of IST crystal TG-DTA studies of doped strontium tartrate crystals TG-DTA studies of ICaT crystal TG-DTA studies of doped calcium tartrate crystals
Highlights of work	• TG-DTA studies of the crystals are made to identify various stages of thermal decomposition of the samples • Thermal conditions at which the grown materials attain thermal stability are identified • The percentage weight loss suffered by the crystals at every stage of their decomposition are observed. Further, these values have also been calculated theoretically • Through appropriate analysis, examination is made as to whether the grown lattices are tetrahydrated or pentahydrated

3.6 Chapter 6: Fourier Transform Infrared and Raman Spectral Studies

Printed structure	Pages: 29 | Sections: 5 | Figures: 13 | Tables: 13 | References: 12
Section headings	Introduction FTIR and Raman studies of IST crystal FTIR and Raman studies of doped strontium tartrate crystals FTIR and Raman studies of ICaT crystal FTIR and Raman studies of doped calcium tartrate crystals
Highlights of work	• FTIR studies are made to identify various functional groups present in the grown crystals • Raman spectroscopic analysis is made to identify various modes of vibrational stretching and bending associated with the bonds formed in the crystals • The spectra are analyzed to study the effect of doping on the crystalline nature of the grown materials • The spectra are examined to observe the effects of doping on the FTIR and Raman spectral structures of the grown samples

3.7 Chapter 7: PXRD, SXRD and HSA Studies of the Grown Crystals

Printed structure	Pages: 61 | Sections: 4 | Figures: 24 | Tables: 10 | References: 4
Section headings	Introduction PXRD studies SXRD studies HSA for the grown intrinsic crystals
Highlights of work	• PXRD spectra of all the grown samples are obtained • The grown materials are analysed to confirm that they are pure and crystalline • The spectra are analyzed to study the effect of doping on the crystalline nature of the grown materials • Structure of ICaT crystal is solved • Hirshfeld surface analysis of the grown intrinsic crystals is made using `Crystal Explorer` software to assess the contribution of hydrogen bonds (both qualitatively and quantitatively) to the crystal structure

3.8 Chapter 8: Optical Studies of the Grown Crystals

Printed structure	Pages: 22 | Sections: 3 | Figures: 14 | Tables: 3 | References: 15
Section headings	Introduction Results 1: UV-Visible-NIR spectral studies of the grown crystals Results 2: Kurtz-Perry powder technique: SHG efficiency of the grown crystals
Highlights of work	• All the crystals are subjected to UV-Visible-NIR spectral studies • The second harmonic generation capability of the crystals is studied • Effect of doping on several optical properties, namely, absorbance, transmittance, bandgap energy and extinction coefficient are studied for the grown crystals • The bandgap and the effect of doping on bandgap energy of the crystals are studied

3.9 Chapter 9: Electrical and Magnetic Studies of the Grown Crystals

Printed structure	Pages: 19 | Sections: 5 | Figures: 26 | Tables: 3 | References: 19
Section headings	Introduction to studies of I-V characteristics Study of I-V characteristics and DC conductivity of the crystals Study of the grown crystals as dielectrics Study of AC conductivity of the crystals Magnetic susceptibility studies
Highlights of work	• I-V characteristics and DC conductivity of the crystals are studied • All the crystals are studied for their dielectric properties • The AC conductivity of the crystals are studied as a function of the applied frequency • Nature of magnetization and magnetic susceptibility of all the grown crystals are studied by using Gouy balance technique

4 Important results

4.1 Chapter 1

1. An extensive survey of literature is made to find that it is scientifically important and meaningful to attempt for synthesizing new, pure and crystalline materials that would be useful for various technological applications, with a special impetus on growth of single crystals by gel method.

4.2 Chapter 2

1. Once the crystals are grown, the crystals need to be characterized as completely as possible so that they are scientifically and technologically assessed for various physical and chemical properties. Various techniques/methods from which this goal is accomplished are:

    - Simulation technique (by WinXMorph software)
    - FESEM technique
    - EDAX technique
    - PXRD technique
    - SXRD & HSA (using `Crystal Clear-SM Expert` and `Crystal Explorer` softwares)
    - FTIR technique
    - Laser-Raman spectroscopy
    - TG-DTA technique

- UV-Visible spectral analysis
- Kurtz and Perry powder technique
- Impedance analyser technique
- Two probe technique and
- Gouy balance methodology

In this chapter, all the above methods/techniques, as used in this study, are explained explicitly and clearly.

4.3 Chapter 3

1. A detailed study of gel method of growing single crystals is made
2. The effect of growth parameters on crystal formation is studied in detail
3. By optimizing the growth parameters, two intrinsic and eleven doped single crystal materials are grown
4. The two intrinsic crystals are strontium tartrate pentahydrate and calcium tartrate tetrahydrate. The dopant materials (metals) used are cobalt, copper, magnesium, manganese, nickel, zinc and cadmium
5. Using simulation technique, the morphologies of the crystals are studied. Various planes of the grown crystals and the relative growth rates of those planes are identified and reported
6. The morphologies of the grown crystals are observed to be generally different from each other and unique

4.4 Chapter 4

1. Using EDAX technique, the elements, including trace elements, present on the surface of the crystals (upto a depth of a few nanometers) are identified to know the purity of the crystal and presence of impurities, if any, in the grown lattices.
2. In order to know the level of doping in the extrinsic crystals, the cationic distribution ratios are determined.
3. In this study, it is confirmed that
   - Among strontium derivatives, while cadmium doped strontium tartrate crystals are heavily doped (cationic distribution ratio: Sr^{2+}:Cd^{2+}=10.43:1), the magnesium doped strontium tartrate crystals are lightly doped with a cationic distribution ratio of 768:1.
   - Likewise, among the calcium derivatives, while CdDCaT crystals are heavily doped with a cationic distribution ratio of Ca^{2+}:Cd^{2+}=38.22:1, the nickel doped calcium tartrate crystals are lightly doped with a cationic distribution ratio of 141.86:1
4. Consequently, the lightly doped materials of this study (MDST & NiDCaT crystals) may be useful as high speed switching and transistor devices, whereas, the heavily doped materials (CdDST & CdDCaT) may be useful as high current carrying devices, such as contacts, interconnects etc.

4.5 Chapter 5

1. The TG-DTA studies indicate that the crystals of this study undergo thermal decomposition in multiple stages before attaining stable state
2. Among strontium tartrate derived crystals (including IST), only MDST crystal is observed to attain stability as carbonate, whereas, other crystals reach stability as oxides
3. The weight loss of crystals observed in the experiment are in agreement with the corresponding weight losses calculated theoretically
4. All calcium tartrate derived crystals (including ICaT) are observed to attain stability in the oxide state
5. The TG-DTA analysis indicates that the grown strontium tartrate crystal lattices contained 5 water molecules (i.e., pentahydrates), while the lattices of calcium tartrate crystals contained 4 water molecules (i.e., tetrahydrates), before undergoing thermal decomposition

4.6 Chapter 6

1. The FTIR and Raman spectral analysis of the grown crystals show
   - Presence of water of crystallization along with the presence of symmetric stretching (O-H, C-H, C-O, C-C & COO^-) and asymmetric (COO^-) stretching modes of vibration in addition to C-H bending, O-H bending & deformation, COO^- twist and C-C torsion modes in the case of the strontium tartrate crystals.
   - Presence of water of crystallization along with the presence of symmetric stretching (O-H, C-H, C-O, C=O, C-C & C-H) modes of vibration, in addition to O-H plane bending and deformation, γ(C=O)+δ(O-C=O), δ(C-H)+π(C-H) modes in the case of calcium tartrate crystals
2. All through these studies, the FTIR data are seen to be complementary to the data from Raman studies.

4.7 Chapter 7

1. The SXRD spectral analysis of this study show that:
   - The crystals belong to orthorhombic system with the space group $P2_12_12_1$
   - The crystals are noncentrosymmetric in nature. This in turn indicates the second order NLO property of the crystal materials.
   - The structure of the ICaT crystal resembles the structure determined by Hawthorne et al [8]
   - Hirshfeld analysis suggests the presence of hydrogen bonds in the intrinsic crystals of this study. The contribution of hydrogen bonds to the crystal structure is also determined using HSA.
2. The indices (h, k, l) for the prominant peaks of the XRD spectra of the crystals are determined

3. The PXRD data on the doped crystals of this study confirm:
    - The crystalline nature of the grown crystals
    - The presence of dopant ions in the host lattice
    - Expansion or contraction of the lattice depending on the type of dopants used

4.8 Chapter 8

1. The Tauc plots of all the crystals show very high bandgap energies, indicating the insulating nature of the crystal materials
2. All the crystals show maximum absorbance peak in the UV region, and show maximum transmittance in the Visible-NIR region: a criterion to be satisfied by a crystal to be applicable as NLO device
3. Doping is observed to decrease the bandgap energy only marginally
4. IST and all of its derivative crystals show second harmonic generation property.
5. All calcium tartrate derivative crystals, except CoDCaT crystal, are observed to work as SHGs
6. Several of the grown crystals of this study appear to be useful as controllers of laser radiation [42] and as high speed processors in telecommunication systems [43]

4.9 Chapter 9

1. The AC conductivity of the crystals is observed to follow Jonscher's Power law.
2. The AC conductivity measurements reveal exponential behaviour indicative of the fact that the operative mechanism for conductivity works as per the tiny polaron hopping concept [44]
3. As the magnetic field applied on a crystal increases, the weight of the crystal is observed to decrease noticeably.
4. All grown crystals of this study exhibit negative molar susceptibility, indicating their diamagnetic nature [20]

5 Conclusions

Gel method of growing single crystals is one of the most convenient and relatively inexpensive methods to produce research quality crystals having large enough size and purity. In the present study, this method is adapted, after optimizing the growth parameters, to grow two intrinsic and eleven types of doped single crystals of strontium tartrate and calcium tartrate.

The grown crystals are subjected to various established standard techniques to know the structure, composition, thermal, electrical, optical and magnetic properties with an intension of characterizing the grown crystals. The crystals exhibit interesting properties, including high temperature

stability, that qualify these materials for use in various applications, as briefly described in the following Table.

Table of possible applications of the grown crystal materials of this study based on the observed characteristic properties	
Grown crystals	**Applications**
All crystals of this study	As transducer in the optical region
MDST (lightly doped) crystal	As high speed switching devices
CuDST, MnDST, CdDST, CoDST & CdDCaT (heavily doped) crystals	As high current electronic devices
All crystals except CoDCaT crystal	As frequency converter
All crystals except CoDCaT crystal	As Laser controller
All crystals of this study	As data storage device
All crystals of this study	As data processor
All crystals of this study	In high temperature electronic applications

6 Publications and Research Work Activities

6.1 In Refereed Journals

1. **Reema K B**, Jagannatha N, Nagaraja K P and D'Souza D: Magnesium and zinc diffused growth and characterization of strontium L (+) tartrate pentahydrate crystals : *Journal Of Advanced Applied Scientific Research*, 3(1), 7–15, 2021.
   ISSN: 2454-3225; https://doi.org/10.46947/joaasr312021113

2. **Reema K B**, Jagannatha N, Nagaraja K P and D'Souza D: Impact of copper doping on thermal, optical and electrical properties of strontium L (+) tartrate pentahydrate crystals: *Journal of Crystal Growth*, 574, 126321, 2021.
   ISSN: 0022-0248; https://doi.org/10.1016/j.jcrysgro.2021.126321.

3. **Reema K B** and Jagannatha N: Growth, elemental analysis, thermal stability and identification of functional groups of intrinsic and manganese doped strontium tartrate pentahydrate single crystals: *International Journal of Innovative Research in Physics*, 2(3), 16–26, 2021.
   ISSN: 2689-484X (PRINT) ISSN: 2687-7902 (ONLINE)

4. **Reema K B** and Jagannatha N: Thermal and optoelectrical properties of cobalt doped and undoped strontium L(+) tartrate pentahydrate single crystals: *Materials Today: Proceedings*, 49, 1323–1330, 2022.
   ISSN: 2214-7853; https://doi.org/10.1016/j.matpr.2021.06.392

5. D'Souza D, Jagannatha N, Nagaraja K P and **Reema K B**: Effect of Cadmium Incorporation on Optical and Electrical Properties of Nickel doped Zinc Phosphate Crystals: *Journal of Applicable Chemistry*, 7(3), 559–568, 2018.
   ISSN: 2278-1862

6. **Reema K B** and Jagannatha N: Elemental analysis and X-ray diffraction studies of cadmium doped strontium tartrate single crystals: *National Research Journal of Information technology and information science*, Vol No 11, Special Issue 2, May 2024
ISSN NO: 2350-1278.

6.2 Papers Presented in Conferences

1. Delma D'Souza, Jagannatha N, Nagaraja K P, Susheela K L and **Reema K B**: Growth and characterization of CO_2^+ and Ni^{2+} doped zinc hydrogen phosphate single crystals: *National conference on nano-materials and nano electronic devices for energy applications*, Indian academy Degree College, Bangalore, Karnataka, India, 28– 29 July 2017.

2. **Reema K B**, Jagannatha N, Nagaraja K P and D'Souza D: Elemental analysis, Optical and Electrical studies of IST and Manganese doped Strontium tartrate single crystals: *International conference on recent advances in materials science and Biophysics (RAMSB)*, Mangalore University, Mangalore, Karnataka, India, 23–25 January 2018.

3. Delma D'Souza, Jagannatha N, Nagaraja K P and **Reema K B**: Thermal and optical properties of co-doped zinc phosphate single crystals: *International conference on recent advances in materials science and Biophysics (RAMSB)*, Mangalore University, Mangalore, Karnataka, India, 23–25 January 2018.

4. **Reema K B**, Jagannatha N, Nagaraja K P and Delma D'Souza: Thermal studies and functional unit's identification of manganese doped strontium tartrate crystals: *International conference on nanomaterials and their applications*, University of Mysore, Mysuru, Karnataka, India, 1–2 March 2018.

5. Delma D'Souza, Jagannatha N, Nagaraja, K P, **Reema K B** and Pradeepkumar K V: Effect of Mg-Mndoping on thermal and optical properties of zinc phosphate crystals: International conference on nanomaterials and their applications, University of Mysore, Mysuru, Karnataka, India, 1–2 March 2018.

6. **Reema K B**, Jagannatha N, Nagaraja K P and Delma D'Souza: Elemental and optical studies of magnesium doped strontium tartrate pentahydrate crystals: *National Conference on Recent advances in material science*, Field Marshal K M Cariappa College, Madikeri, Karnataka, India, 5 February 2019.

7. Delma D'Souza, Jagannatha, N, Nagaraja, K P, **Reema K B** and Pradeepkumar K V: Optical and electrical properties of Nickel doped Zinc Phosphate crystals: *National conference on recent advances in material science*, Field Marshal K M Cariappa College, Madikeri, Karnataka, India, 5 February 2019.

8. **Reema K B**, Jagannatha N, Delma D'Souza and Nagaraja K P: Elemental and Optical studies of ISTP and magnesium doped strontium tartrate pentahydrate crystals: *International Conference on Advanced Functional Materials for Energy, Environment and Health Care (AFMEEHC)*, at the Center for materials science and Technology, Vijnan Bhavan, University of Mysore, Mysuru, Karnataka, India, 18–20 March 2019.

9. Delma D'Souza, Jagannatha N, Nagaraja K P, **Reema K B**, Ganavi A S and Mangala M. Sanjeevannanavar: Thermal and electrical properties of cadmium doped zinc oxalate crystals: *National conference on recent novel approaches in chemical sciences*, Field Marshal K M Cariappa College, Madikeri, Karnataka, India, 12 February 2020.

10. **Reema K B**, Jagannatha N, Nagaraja K P and Delma D'Souza: Growth and optical studies of cadmium doped strontium L(+) tartrate pentahydrate crystals: *International virtual conference of solid state materials*, Department of physics, St Aloysius college (Autonomous), Mangalore, Karnataka, India, 2–3 September 2020.

11. Rohith P S, Jagannatha N, Kumar K P, D'Souza D and **Reema K B**: Effect of Barium Incorporation on Thermal and Optical Properties of Copper Mixed Cadmium Oxalate Single Crystals: *Applied Materials and Technology 2020, An Approach to Trans Disciplinary Research*, Department of Physics, KLE Societie's S Nijalingappa College, Rajajinagar, Bengaluru, Karnataka, India, 560010, 9-10 October 2020.

12. **Reema K B**, Jagannatha N, Nagaraja K P and Delma D'Souza: Impact of copper doping on thermal, optical and electrical properties of strontium L(+) tartrate pentahydrate crystals: *8th Asian Conference on Crystal Growth and Crystal Technology (CGCT-8)*, Online (all-Virtual) Conference, 1–4 March 2021.

13. **Reema K B** and Jagannatha N: Growth, elemental analysis, thermal stability and identification of functional groups of intrinsic and manganese doped strontium tartrate Pentahydrate single crystals: *International Conference on advanced physics 2021 (IEMPHYS 2021)*, Institute of Engineering & Management, Kolkata, West Bengal, India, 1–3 April 2021.

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